

Patent Application Transmittal

(only for new nonprovisional applications under 37 C.F.R. 1.53(b))

Correspondence Address:

FROMMER LAWRENCE &amp; HAUG LLP

745 FIFTH AVENUE

NEW YORK, NEW YORK 10151

TEL: (212) 588-0800

FAX: (212) 588-0500

jc511 U.S. PTO

09/479281

01/06/00

Date: January 6, 2000Attorney Docket No.: 450117-02159

ASSISTANT COMMISSIONER FOR PATENTS

Box Patent Application

Washington, D.C. 20231

Sir:

With reference to the filing in the United States Patent and Trademark Office of an application for patent in the name(s) of:

Ralf BOHNKE, Thomas DOLLE, Tino KONSCHAK

entitled:

SYNCHRONIZATION SYMBOL STRUCTURE USING OFDM BASED TRANSMISSION METHOD

The following are enclosed:

- ☒ Specification ( 11 pages)  
☒ 9 Sheet(s) of Drawings  
☒ 27 Claim(s) (including 2 independent claim(s))  
☐ This application contains a multiple dependent claim

- ☒ Our check for \$ 856.00, calculated on the basis of the claims as amended by any enclosed preliminary amendment as follows:

Basic Fee, \$690.00 (\$345.00)	\$ 690.00
Number of Claims in excess of 20 at \$18.00 (\$9.00) each: 7	126.00
Number of Independent Claims in excess of 3 at \$78.00 (\$39.00) each:	-0-
Multiple Dependent Claim Fee at \$260.00 (\$130.00)	-0-
Total Filing Fee	\$ 816.00

- ☒ Assignment Recording Fee \$40.00 \$ 40.00

- ☒ Oath or Declaration and Power of Attorney

☒ New ☒ signed ☐ unsigned  
☐ Copy from a prior application (37 C.F.R. 1.63(d))

- ☒ Certified copy of each of the following application(s) to substantiate the claim(s) for priority made in the Declaration:

<u>Application No.</u>	<u>Filed</u>	<u>In</u>
EP99 103 379.6	22 February 1999	Europe
EP99 100 263.5	8 January 1999	Europe

Please charge any additional fees required for the filing of this application or credit any overpayment to Deposit Account No. 50-0320.

Respectfully submitted,

FROMMER LAWRENCE & HAUG LLP  
 Attorneys for Applicants

By: 

Dennis M. Smid  
 Reg. No. 34,930

450117-02159

"Express Mail" mailing label number EL375193501US

Date of Deposit January 6, 2000



I hereby certify that this paper or fee, and a patent application and accompanying papers, are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and are addressed to the Assistant Commissioner for Patents, Washington, DC 20231.

SCANNED 1

Charles Jackson

(Typed or printed name of person mailing paper or fee)

Charles Jackson

(Signature of person mailing paper or fee)

PATENT  
450117-02159

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants : Ralf BOHNKE et al.  
Filed : Herewith  
For : SYNCHRONIZATION SYMBOL STRUCTURE USING OFDM BASED  
TRANSMISSION METHOD

745 Fifth Avenue  
New York, New York 10151  
Tel. (212) 588-0800

EXPRESS MAIL

Mailing Label Number EL375193501US  
Date of Deposit January 6, 2000  
I hereby certify that this paper or fee is being  
deposited with the United States Postal Service  
"Express Mail Post Office to Addressee" Service  
under 37 CFR 1.10 on the date indicated above and  
is addressed to the Assistant Commissioner for  
Patents, Washington, D.C. 20231

Charles J. ...  
(Typed or printed name of person  
mailing paper or fee)

Charles J. ...  
(Signature of person mailing paper or fee)

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents  
Washington, D.C. 20231

Sir:

Before the issuance of the first Official Action,  
please amend the above-identified application as follows:

IN THE CLAIMS:

Please amend the claims as follows:

Claim 3, line 1, change "anyone of the preceding  
claims" to --claim 1--;

Claim 4, line 1, change "anyone of the preceding  
claims" to --claim 1--;

009076" T8262460

Claim 5, line 1, change "anyone of the preceding  
claims" to --claim 1--;

Claim 6, line 1, change "anyone of the preceding  
claims" to --claim 1--;

Claim 7, line 1, change "anyone of claims 1 to 5" to --  
claim 1--;

Claim 8, line 1, change "anyone of claims 1 to 5" to --  
claim 1--;

Claim 9, line 1, change "anyone of claims 1 to 5" to --  
claim 1--;

Claim 10, line 1, change "anyone of claims 1 to 5" to -  
-claim 1--;

Claim 11, lines 3-4, change "according to anyone of the  
preceding claims" to --claim 1--;

Claim 13, line 1, change "anyone of the preceding  
claims" to --claim 1--;

Claim 16, line 1, change "anyone of claims 14 or 15" to  
--claim 14--;

Claim 17, line 1, change "anyone of claims 14 or 15" to  
--claim 14--;

Claim 19, line 1, change "anyone of claims 14 to 18" to  
--claim 14--;

Claim 20, line 1, change "anyone of the claims 14 to  
19" to --claim 14--;

Claim 21, line 1, change "anyone of claims 14 to 19" to  
--claim 14--;

Claim 22, line 1, change "anyone of claims 14 to 19" to  
--claim 14--;

Claim 23, line 1, change "anyone of claims 14 to 19" to  
--claim 14--;

Claim 24, line 1, change "anyone of claims 14 to 19" to  
--claim 14--;

Claim 25, line 1, change "anyone of claims 14 to 24" to  
--claim 14--;

Claim 26, line 1, change "anyone of the claims 14 to  
25" to --claim 14--;

Claim 27, line 2, change "anyone of claims 14 to 26" to  
--claim 14--.

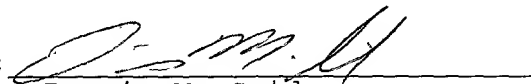
REMARKS

The claims have been amended herein to eliminate  
multiple dependencies. The filing fee has been calculated based  
upon these amendments to the claims.

Respectfully submitted,

FROMMER LAWRENCE & HAUG LLP  
Attorneys for Applicants

By:



Dennis M. Smid  
Reg. No. 34,930  
Tel. (212) 588-0800

PATENT  
450117-02159

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE  
APPLICATION FOR LETTERS PATENT

TITLE: SYNCHRONIZATION SYMBOL STRUCTURE USING  
OFDM BASED TRANSMISSION METHOD

INVENTORS: Ralf BOHNKE, Thomas DOLLE, Tino  
KONSCHAK

William S. Frommer  
Registration No. 25,506  
Dennis M. Smid  
Registration No. 34,930  
FROMMER LAWRENCE & HAUG LLP  
745 Fifth Avenue  
New York, New York 10151  
Tel. (212) 588-0800

0093070-78262450

Sony International (Europe) GmbH  
 Sony Ref.: S99P5001EP01-PAE98-012TRDE  
 Our Ref.: P21861EP/P1

5

Synchronization symbol structure using OFDM based transmission method

10 The present invention relates to a method for generating synchronization bursts for OFDM transmission systems, a method for synchronizing wireless OFDM systems, an OFDM transmitter as well as to a mobile communications device comprising such a transmitter.

15 The present invention relates generally to the technical field of synchronizing wireless OFDM (orthogonal frequency division multiplexing) systems. Thereby it is known to use a synchronization burst constructed using especially designed OFDM symbols and time domain repetitions.

20 Particularly from the document IEEE P802.11a/d2.0 "Draft supplement to a standard for telecommunications and information exchange between systems - LAN/MAN specific requirements - part 1: wireless medium access control (MAC) and physical layer (PHY) specifications: high-speed physical layer in the 5 GHz band" a synchronization scheme for OFDM systems is proposed. This document is herewith  
 25 included by reference as far as it concerns the synchronization including the proposed implementation. Said known scheme will now be explained with reference to fig. 6 to 8 of the enclosed drawings.

Fig. 6 shows the structure of the known synchronization field. As shown in Fig. 6 the  
 30 synchronization field consists of so-called short symbols t1, t2,.....t6 and two long symbols T1, T2. In view of the present invention particularly the short symbols t1, t2....t6 are of interest. Among the short symbols t1, t2, ....t6 used for the amplifier gain control (t1, t2, t3) and the course frequency offset and timing control only the symbols t1, t2, t3 and t4 are actually generated, whereas the symbols t5, t6 are cyclic  
 35 extensions (copies of the symbols t1 and t2, respectively). It is to be noted that fig. 5 shows only the synchronization preamble structure as the structure of the following signal field indicating the type of baseband modulation and the coding rate as well as the structure of further following data fields are not of interest in view of the present invention. For further details reference is made to said prior art document.

40

The symbols t1, t2, t3, t4 are generated by means of an OFDM modulation using selected subcarriers from the entire available subcarriers. The symbols used for the OFDM modulation as well as the mapping to the selected subcarriers will now be explained with reference to fig. 6.

5

Each of the short OFDM symbols t1, ....t6 is generated by using 12 modulated subcarriers phase-modulated by the elements of the symbol alphabet:

$$S = \sqrt{2}(\pm 1 \pm j)$$

10

The full sequence used for the OFDM modulation can be written as follows:

$$S_{-24, 24} = \sqrt{2} * \{ 1+j, 0,0,0, 1+j, 0,0,0, -1-j, 0,0,0, -1-j, 0,0,0, 1-j, 0,0,0, -1-j, 0,0,0, 0, 0, 0, 0, 1+j, 0,0,0, 1+j, 0,0,0, -1-j, 0,0,0, 1+j, 0,0,0, -1-j, 0,0,0, 1+j \}$$

15

The multiplication by a factor of  $\sqrt{2}$  is in order to normalize the average power of the resulting OFDM symbol.

The signal can be written as:

20

$$r_{SHORT}(t) = w_{SHORT}(t) \sum_{k=-N_F/2}^{N_F/2} S_k \exp(j2\pi k \Delta_F t)$$

The fact that only spectral lines of  $S_{-24, 24}$  with indices which are a multiple of 4 have nonzero amplitude results in a periodicity of  $T_{FFT}/4 = 0.8 \mu\text{sec}$ . The interval  $T_{SHORT1}$  is equal to nine  $0.8 \mu\text{sec}$  periods, i.e.  $7.2 \mu\text{sec}$ .

25

Applying a 64-point IFFT to the vector S, where the remaining 15 values are set to zero, four short training symbols t1, t2, t3, t4 (in the time domain) can be generated. The IFFT output is cyclically extended to result in 6 short symbols t1, t2, t3, ...t6. The mapping scheme is depicted in fig. 7. The so called virtual subcarriers are left unmodulated.

30

The way to implement the inverse Fourier transform is by an IFFT (Inverse Fast Fourier Transform) algorithm. If, for example, a 64 point IFFT is used, the coefficients 1 to 24 are mapped to same numbered IFFT inputs, while the coefficients -24 to -1 are copied into IFFT inputs 40 to 63. The rest of the inputs, 25 to 39 and the 0 (DC) input, are set to zero. This mapping is illustrated in Fig. 7. After performing an IFFT the output is cyclically extended to the desired length.

35



With the proposed inverse fast Fourier transform (IFFT) mapping as shown in fig. 7 the resulting time domain signal consists of 4 periodically repeated short symbols t1, t2, t3, t4, and cyclically extended by a copy of t1, t2, which copy is depicted in fig.5 as t5, t6.

- 5 Note that in the present case only spectral lines with indices which are a multiple of 4 have nonzero amplitude. Other periodic natures can be generated by setting other multiples of the spectral lines to nonzero amplitudes.

- 10 Though the known synchronization scheme is very effective, it provides for disadvantage regarding the time domain signal properties.

- 15 For OFDM (or in general multicarrier signals) the signal envelope fluctuation (named Peak-to-Average-Power-Ratio=PAPR) is of great concern. A large PAPR results in poor transmission (due to nonlinear distortion effects of the power amplifier) and other signal limiting components in the transmission system (e.g. limited dynamic range of the AD converter).

- 20 For synchronization sequences it is even more desirable to have signals with a low PAPR in order to accelerate the receiver AGC (automatic gain control) locking and adjusting the reference signal value for the A/D converter (the whole dynamic range of the incoming signal should be covered by the A/D converter resolution without any overflow/underflow).

- 25 Figures 8a, 8b show the "absolute" ( $\sqrt{\text{In}^2 + \text{Quad}^2}$ ) value of the resulting time domain signal waveform with the sequences proposed by Lucent Technologies. Oversampling (8\*) was considered in order to ensure the peak was captured correctly using the limited 64-point IFFT.

- 30 Figures 8c, 8d show the real and imaginary part of the resulting transmitted time domain waveform. The resulting PAPR is 2.9991 dB (no oversampling) and 3.0093 dB (with 8 times oversampling).

- 35 Therefore it is the object of the present invention to provide for a synchronization technique which bases on the known synchronization technique but which presents improved time domain signal properties to reduce the requirements for the hardware.

The above object is achieved by means of the features of the independent claims. The dependent claims develop further the central idea of the present invention.

According to the present invention therefore a method for generating synchronization bursts for OFDM transmission systems is provided. Symbols of a predefined symbol sequence are mapped according to a predefined mapping scheme on subcarriers of the OFDM system wherein the symbols of the predefined symbol sequence represent subcarriers with nonzero amplitudes. A synchronization burst is generated by inverse fast Fourier transforming the subcarriers mapped with a predefined symbol sequence. According to the present invention the predefined symbol sequence is optimized such that the envelope fluctuation of the time domain signal (Peak-to-average-power-ratio) is minimized.

The predefined symbol sequence can be chosen such that the following equations are satisfied for all symbols of the predefined symbol sequence:

$$\begin{aligned} n &= 2m, \\ C_{i-1} &= \pm C_{i+1}, \end{aligned}$$

$n$  being the number of symbols of the predefined symbol sequence,  
 $m$  being an integer larger than one,  
 $C$  being the symbol value, and  
 $i$  being an integer running from 1 to  $m$ .

The mapping of the symbols of the predefined symbol sequence and the Inverse Fast Fourier Transform can be set such that the resulting time domain signal of the synchronization burst represents a periodic nature.

Alternatively the mapping of the symbols of the predefined symbol sequence and the Inverse Fast Fourier Transform is set such that one burst part of the synchronization burst in the time domain is generated and the periodic nature of the synchronization burst in the time domain is achieved by copying the one burst part.

The number of symbols of a symbol sequence ( $n$ ) can for example be 12.

The above equations define generally the symbol sequences according to the present invention. The predefined symbol sequence can therefore be for example:

$A \quad A \quad A \quad -A \quad -A \quad -A \quad -A \quad A \quad -A \quad -A \quad A \quad -A,$   
 wherein  $A$  is a complex value.

Alternatively the predefined symbol sequence can be:

A    -A    A    A    -A    A    A    A    A    -A    -A    -A,  
wherein A is a complex value.

5    Alternatively the following predefined symbol sequence can be used:

A    B    -A    B    -A    -B    B    A    -B    A    -B    -A,  
wherein A, B are complex values.

As a further alternative the following sequence can be used:

10    A    -B    -A    -B    -A    B    -B    A    B    A    B    -A,  
wherein A, B are complex values.

According to the present invention furthermore a method for synchronizing wireless OFDM systems is provided, wherein a synchronization burst is generated according to a method as set forth above and the synchronization burst is transmitted respectively before the transmission of data fields.

Thereby the time domain signals of the synchronization burst can be precomputed and stored in a memory, such that the computation of the time domain signal of the burst is only effected once.

According to the present invention furthermore a OFDM transmitter is provided comprising a mapping unit for mapping the symbols of a predefined symbols sequence according to a predefined mapping scheme on subcarriers of the OFDM system, wherein the symbols of a predefined symbols sequence represent the subcarriers of the OFDM system with nonzero amplitudes. Furthermore an inverse fast Fourier transforming unit is provided for generating a synchronization burst by inverse fast Fourier transforming the subcarriers of the OFDM mapped with said predefined symbols sequence. The mapping unit thereby is designed such that the resulting time domain signal of the synchronization burst represents a periodic nature. The mapping unit according to the present invention uses a predefined symbol sequence which is such that the envelope fluctuation of the time domain signal of the synchronization burst is minimized.

35    According to the present invention furthermore a mobile communications device such as set forth above is used.

With reference to the figures of the enclosed drawings referred embodiments of the present invention will now be explained.

Fig. 1 shows schematically a transmitter according to the present invention,

5 Fig. 2 shows an alternative embodiment for a transmitter according to the present invention,

Fig.3 shows an alternative mapping scheme according to the present invention,

10

Fig. 4a to 4d show the time domain signal properties achieved with the synchronization symbol structure using OFDM based transmission according to the present invention,

15

Fig. 5a to 5d show the time domain signal properties of synchronization symbol structures according to alternative embodiments of the present invention,

20

Fig. 6 shows a synchronization preamble structure known from the prior art,

Fig. 7 shows an IFFT mapping according to the prior art, and

25

Fig. 8a to 8d show the time domain properties of the synchronization symbol structure according to the prior art,

Fig. 9a and 9b show the time domain properties, particularly the dynamic range of the synchronization symbol structure according to the prior art, and

30

Fig. 10a and 10b show the time domain properties of the synchronization symbol structure according to further alternative embodiments of the present invention,

35 According to the present invention the time domain synchronization burst structure as shown in Fig. 6 is maintained. The IFFT mapping as shown in Fig. 7 can be maintained or alternatively the IFFT mapping according to figure 3 can be used. The symbol sequences mapped to the subcarriers are optimized to sequences which result in a lower PAPR.

According to the present invention a short OFDM symbol (t1,...t6) consists of 12 phase-modulated subcarriers.

	C00	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11
Seq0	A	A	A	-A	-A	-A	-A	A	-A	-A	A	-A
Seq1	A	-A	A	A	-A	A	A	A	A	-A	-A	-A
Seq2	A	B	-A	B	-A	-B	B	A	-B	A	-B	-A
Seq3	A	-B	-A	-B	-A	B	-B	A	B	A	B	-A

5

with  $A = \exp(j*2 + \pi*\varphi_A)$  and  $B = A*\exp(j\frac{\pi}{2}) = \exp(j2\pi*\varphi_A + j\frac{\pi}{2})$  and  $0.0 \leq \varphi_A < 1.0$ .

Generally the predefined symbol sequence therefore is chosen such that the envelope fluctuation of the time domain signal of the synchronization burst is minimized.

10 Therefore generally the predefined symbol sequence is set such that the following equations are satisfied for all symbols for the predefined symbol sequence:

$$\begin{aligned} n &= 2m, \\ C_{i-1} &= \pm C_{n-i} \end{aligned}$$

15

wherein n is a number of symbols of the predefined symbol sequence,

m is an integer larger than 1,

c is the symbol value, and

i is an integer value running from 1 to m.

20

In the following the time domain signal properties of the new sequences according to the present invention will be shown with reference to Fig. 4a to 4d and Fig. 5a to 5d.

For simplicity we use in our demonstration the classical quadriphase symbol alphabet,

25

$$S = \sqrt{\frac{1}{2}} (\pm 1 \pm j),$$

(this corresponds to  $\varphi_A = 0.125$ )

Symbol		
A	$\exp(j\frac{\pi}{4})$	$\sqrt{\frac{1}{2}} (+1+j)$

-A	$-\exp(j\frac{\pi}{4})=\exp(j\frac{5\pi}{4})$	$\sqrt{\frac{1}{2}}(-1-j)$
B	$\exp(j\frac{\pi}{4}+j\frac{\pi}{2})=\exp(j\frac{3\pi}{4})$	$\sqrt{\frac{1}{2}}(-1+j)$
-B	$-\exp(j\frac{3\pi}{4})=\exp(j\frac{7\pi}{4})$	$\sqrt{\frac{1}{2}}(+1-j)$

Table 1: Complex symbol mapping

Fig. 5a and 5b thereby show the time domain signal (magnitude) when using the optimized sequence according to the present invention in the case of no oversampling/8-times oversampling is effected.

PAPR (in decibel) is limited to 2.059 (even when using a time domain oversampling to capture the actual peak).

Fig. 5c and 5d show the in-phase and quadrature-phase component, respectively, of the resulting wave form. It is clearly visible that the full symbol consists of four repetitions of a short sequence.

Fig. 5a to 5d show graphics corresponding to Fig. 4a to 4d for the other proposed sequences S1, S2 and S3.

Further simulations have shown that not only the PAPR can be optimized but also the dynamic range of the signal should be minimized. Therefore another four sequences, with achieve a small PAPR and at the same time a small overall dynamic range are proposed further below.

Using the sequence as proposed in the state of the art the PAPR is 3.01 dB and the dynamic range (defined as the ratio of the peak power to the minimum power) is 30.82 dB (see figures 9a and 9b).

Using the sequences according to the present invention and as described above the PAPR is reduced to 2.06 dB, however, the dynamic range is increased as the signal power is '0' at some points.

Therefore the following four sequences are proposed as a further embodiment of the present invention:

The symbol sequence is C0, C1, ..., C11 and the mapping is:

$$S = 2 * \{ \text{C00}, 0, 0, 0, \text{C01}, 0, 0, 0, \text{C02}, 0, 0, 0, \text{C03}, 0, 0, 0, \text{C04}, 0, 0, 0, \\ \text{C05}, 0, 0, 0, 0, 0, 0, 0, \text{C06}, 0, 0, 0, \text{C07}, 0, 0, 0, \text{C08}, 0, 0, 0, \text{C09}, 0, 0, 0, \\ \text{C10}, 0, 0, 0, \text{C11} \}$$

	C00	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11
Seq-Alt0	A	A	A	A	-A	-A	A	-A	-A	A	-A	A
Seq-Alt1	A	-A	A	-A	-A	A	-A	-A	A	A	A	A
Seq-Alt2	A	B	-A	-B	-A	-B	-B	-A	-B	-A	B	A
Seq-Alt3	A	-B	-A	B	-A	B	B	-A	B	-A	-B	A

with  $A = \exp(j*2*\pi*\varphi_A)$  and  $B = A * \exp(j\frac{\pi}{2}) = \exp(j2\pi*\varphi_A + j\frac{\pi}{2})$  and  $0.0 \leq \varphi_A < 1.0$ .

Using these sequences the PAPR is reduced to 2.24 dB and the dynamic range is limited to 7.01 dB as it is shown in figures 10 a and 10b.

The advantages are the same as described before, however, the clipping problem is further reduced due to the very limited dynamic range of the signal.

With reference to Fig. 1 and 2 possible implementations of a transmitter according to the present invention will now be explained.

In the transmitter the sync symbol data 1 are prepared and mapped in a IFFT mapping unit 2 to the appropriate IFFT points. The subcarriers of the OFDM system are transformed by a IFFT unit 3 and then the time domain signal is extended in a time extension unit 4 by copying parts of the signals (for example, t1, t2 are copied to t5, t6). The time extended signal is then sent to the I/Q modulator 5.

As shown in Fig. 2 alternatively the time domain signal can be precomputed once in a computation unit 7 and then be stored in a memory 6 for the precomputed sample for the time signal. Then the time domain signal of the synchronization burst can be sent to the modulator 5 directly from the memory 6.

With reference to figure 3 a modified IFFT mapping scheme will now be explained. According to this scheme, the principle of setting only every fourth subcarrier of the OFDM system to a non-zero amplitude (see figure 7) is abandoned. Therefore the time

domain signal achieved according to the mapping scheme of figure 3 will not present a periodic nature.

The IFFT size is now only 16 (instead of 64 as it is the case in figure 7). Only one of the bursts  $t_1, t_2, \dots, t_6$  will be generated. The other bursts can be generated by copying to retain the periodic nature of the synchronization time domain signal necessary for the correlation and synchronization on the receiving side. Therefore for example the time extension unit 4 can perform the copying of the 16-sample burst  $t_1$  generated by the IFFT 16 according to figure 7 to the other burst  $t_2, t_3, \dots, t_6$ . Obviously the mapping scheme according to figure 3 reduces the computing effort necessary for the IFFT. The periodic nature of the time domain signal of the SYNCH bursts is therefore no longer achieved by the IFFT step, but by copying the burst  $t_1$  generated with the simplified IFFT mapping scheme.

The mapping scheme shown in figure 3 is also advantageous in combination with the precomputing technique shown in figure 2.

According to the present invention therefore a synchronization burst structure to be used in high speed wireless transmission systems is proposed. The synchronization burst is constructed using especially designed OFDM symbols and time domain repetitions. The resulting synchronization burst achieves a high timing detection and frequency offset estimation accuracy. Furthermore the burst is optimized to achieve a very low envelope fluctuation (Low peak-to-average-power-ratio) to reduce the complexity on the receiver and to reduce time and frequency acquisition time at the receiver.

Therefore the synchronization performance can further be improved. As with the scheme according to the present invention the envelope of the OFDM based synchronization burst in the time domain is reduced, the AGC pool-in speed at the receiver can be improved and an accurate time and frequency synchronization can be achieved. Furthermore the synchronization complexity on the receiver side can be reduced due to the reduced resolution requirements necessary due to reduced envelope fluctuation.

The advantages of the present invention can be set forth as following:

- An OFDM based SYNCH symbol with a reduced Peak-to-Average-Power-Ratio (PARP) is proposed,
- Improved synchronization performance (compared to the state of the art proposal),



- Reduced AGC (automatic gain control) pull-in time due to reduced dynamic range of the SYNCH burst,
- Improved AGC settlement (AGC has to adjust to a incoming signal level that later on now overflow/underflow in the AD happens. The reduced dynamic range of the SYNCH burst help to find this reference level more accurate),
- Reduced synchronization detection complexity on the receiver (reduced resolution necessary due to reduced envelope fluctuation).

Sony International (Europe) GmbH  
 Sony Ref.: S99P5001EP01-PAE98-012TRDE  
 Our Ref.: P21861EP/P1

5

Claims:

1. Method for generating synchronization bursts for OFDM transmission systems,  
 10 comprising the following steps:
- mapping (2) the symbols of a predefined symbol sequence according to a predefined mapping scheme on subcarriers of the OFDM system, wherein the symbols of the predefined symbol sequence represent subcarriers of the OFDM system with non-zero-amplitudes, and
  - 15 - generating a synchronization burst by Inverse Fast Fourier Transforming (3) the subcarriers of the OFDM system mapped with the symbols of said predefined symbol sequence,
- c h a r a c t e r i z e d   i n   t h a t
- the predefined symbol sequence is set such that the envelope fluctuation of the time  
 20 domain signal of the synchronization burst is minimized.
2. Method according to claim 1,  
 characterized in that  
 the predefined symbol sequence is chosen such that the following equations are satisfied  
 25 for all symbols of the predefined symbol sequence:
- $$n = 2m,$$
- $$C_{i-1} = \pm C_{n-i}$$
- wherein:
- n is the number of symbols of the predefined symbol sequence,
  - 30 m is an integer larger than one,
  - C is the symbol value, and
  - i is an integer running from 1 to m.
3. Method according to anyone of the preceding claims,

09479331-010600

characterized in that

the mapping (2) of the symbols of the predefined symbol sequence and the Inverse Fast Fourier Transform is set such that the resulting time domain signal of the synchronization burst represents a periodic nature.

5

4. Method according to anyone of the preceding claims,  
characterized in that

the mapping (2) of the symbols of the predefined symbol sequence and the Inverse Fast Fourier Transform is set such that one burst part of the synchronization burst in the  
10 time domain is generated and the periodic nature of the synchronization burst in the time domain is achieved by copying the one burst part.

5. Method according to anyone of the preceding claims,  
characterized in that

15 the number of symbols of a symbol sequence  $n$  is equal to 12.

6. Method according to anyone of the preceding claims,  
characterized in that

the symbol values  $C$  of the predefined symbol sequence can be expressed as:

20  $A \quad A \quad A \quad -A \quad -A \quad -A \quad -A \quad A \quad -A \quad -A \quad A \quad -A,$   
 $A$  being a complex value.

7. Method according to anyone of claims 1 to 5,  
characterized in that

25 the symbol values  $C$  of the predefined symbol sequence can be expressed as:

$A \quad -A \quad A \quad A \quad -A \quad A \quad A \quad A \quad A \quad -A \quad -A \quad -A$   
 $A$  being a complex value.

8. Method according to anyone of claims 1 to 5,

30 characterized in that

the symbol values  $C$  of the predefined symbol sequence can be expressed as:

$A \quad B \quad -A \quad B \quad -A \quad -B \quad B \quad A \quad -B \quad A \quad -B \quad -A$

A, B being complex values.

9. Method according to anyone of claims 1 to 5,  
characterized in that

5 the symbol values C of the predefined symbol sequence can be expressed as:

A    -B    -A    -B    -A    B    -B    A    B    A    B    -A

A, B being complex values.

10. Method according to anyone of claims 1 to 5,

10 characterized in that

the symbol values C of the predefined symbol sequence can be expressed as:

A    -B    -A    B    -A    B    B    -A    B    -A    -B    A

A, B being complex values.

15 11. Method for synchronizing wireless OFDM systems,  
characterized by the steps of

- generating a synchronization burst according to a method according to anyone of the preceding claims, and
- transmitting the synchronization burst.

20

12. Method according to claim 11,  
characterized in that

the time domain signal of the synchronization burst is precomputed (7) and stored in a memory (6).

25

13. Method according to anyone of the preceding claims,  
characterized in that

the predefined symbol sequence is set such that the dynamic range of the time domain signal is minimized.

30

14. OFDM transmitter,  
comprising:

- a mapping unit (2) for mapping the symbols of a predefined symbol sequence according to a predefined mapping scheme on subcarriers of the OFDM system, wherein the symbols of the predefined symbol sequence represent subcarriers of the OFDM system with non-zero amplitudes, and
- 5 - an Inverse Fast Fourier Transforming unit (3) for generating a synchronization burst by Inverse Fast Fourier Transforming (3) the subcarriers of the OFDM system mapped with the symbols of said predefined symbol sequence, characterized in that the mapping unit (2) uses a predefined symbol sequence which is set such that the
- 10 envelope fluctuation of the time domain signal of the synchronization burst is minimized.

15. OFDM transmitter according to claim 14, characterized in that
- 15 the predefined symbol sequence is set such that the following equations are satisfied for all symbols of the predefined symbol sequence:

$$n = 2m,$$

$$C_{i-1} = \pm C_{n-i}$$

wherein:

- 20 n is the number of symbols of the predefined symbol sequence,  
m is an integer larger than one,  
C is the symbol value, and  
i is an integer running from 1 to m.

- 25 16. OFDM transmitter according to anyone of claims 14 or 15, characterized in that the mapping unit (2) is designed such that the resulting time domain signal of the synchronization burst represents a periodic nature.

- 30 17. OFDM transmitter according to anyone of claims 14 or 15, characterized in that

the mapping unit (2) is designed such that one burst part of the synchronization burst in the time domain is generated and the periodic nature of the synchronization burst in the time domain is achieved by copying the one burst part.

- 5 18. OFDM transmitter according to claim 17,  
characterized in that  
a time extension unit (4) copies the burst part to achieve a periodic nature of the time domain signal.

- 10 19. OFDM transmitter according to anyone of claims 14 to 18,  
characterized in that  
the number of symbols of a symbol sequence  $n$  is equal to 12.

20. Transmitter according to anyone of the claims 14 to 19,  
15 characterized in that  
the symbol values  $C$  of the predefined symbol sequence can be expressed as:  
 $A \quad A \quad A \quad -A \quad -A \quad -A \quad -A \quad A \quad -A \quad -A \quad A \quad -A$ ,  
 $A$  being a complex value.

- 20 21. Transmitter according to anyone of claims 14 to 19,  
characterized in that  
the symbol values  $C$  of the predefined symbol sequence can be expressed as:  
 $A \quad -A \quad A \quad A \quad -A \quad A \quad A \quad A \quad A \quad -A \quad -A \quad -A$   
 $A$  being a complex value.

- 25 22. Transmitter according to anyone of claims 14 to 19,  
characterized in that  
the symbol values  $C$  of the predefined symbol sequence can be expressed as:  
 $A \quad B \quad -A \quad B \quad -A \quad -B \quad B \quad A \quad -B \quad A \quad -B \quad -A$   
30  $A, B$  being complex values.

23. Transmitter according to anyone of claims 14 to 19,

characterized in that

the symbol values  $C$  of the predefined symbol sequence can be expressed as:

$A \quad -B \quad -A \quad -B \quad -A \quad B \quad -B \quad A \quad B \quad A \quad B \quad -A$

$A, B$  being complex values.

5

24. Transmitter according to anyone of claims 14 to 19,

characterized in that

the symbol values  $C$  of the predefined symbol sequence can be expressed as:

$A \quad -B \quad -A \quad B \quad -A \quad B \quad B \quad -A \quad B \quad -A \quad -B \quad A$

10  $A, B$  being complex values.

25. Transmitter according to anyone of claims 14 to 24,

characterized by

a processing unit (7) for precomputing the time domain signal of the synchronization

15 burst and a memory (6) for storing the precomputed time domain signal of the synchronization burst.

26. Transmitter according to anyone of the claims 14 to 25,

characterized in that

20 the predefined symbol sequence is set such that the dynamic range of the time domain signal is minimized.

27. Mobile communications device,

comprising a transmitter according to anyone of claims 14 to 26.

25

Sony International (Europe) GmbH  
Sony Ref.: S99P5001EP01-PAE98-012TRDE  
Our Ref.: P21861EP/P1

5

Abstract

The present invention proposes a method for generating synchronization bursts for OFDM transmission systems. The symbols of a predefined symbol sequence are mapped according to a predefined mapping scheme on subcarriers of the OFDM systems by a mapping unit (2), wherein the symbols of the predefined symbol sequence represent subcarriers of the OFDM system with nonzero amplitudes. A synchronization burst is generated by a inverse fast Fourier transforming unit (3) transforming the subcarriers of the OFDM system mapped to said predefined symbol sequence. The mapping (2) of the symbols of the predefined symbol sequence is set such that the resulting time domain signal of the synchronization burst represents a periodic nature. According to the invention the predefined symbol sequence is set such that the envelope fluctuation of the time domain signal of the synchronization burst is minimized. Therefore advantageous symbol sequences reducing said the envelope fluctuation of the time domain signal are proposed.

20

Fig. 1





FIG 3

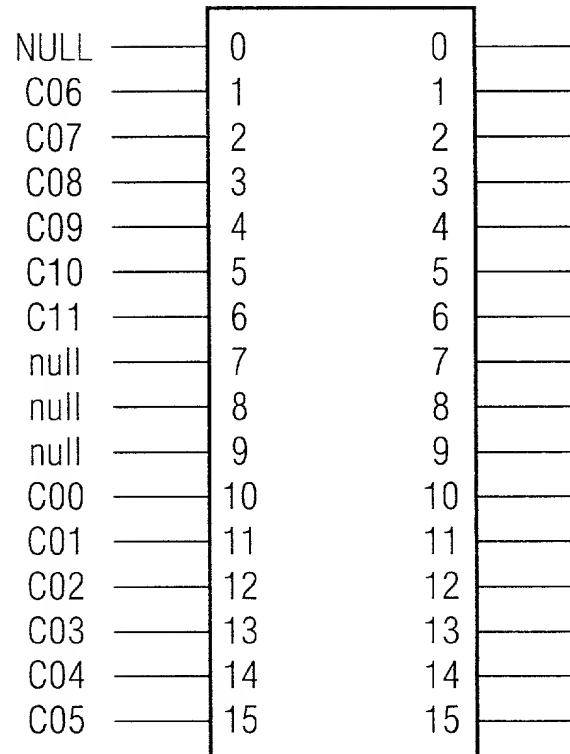


FIG 4a

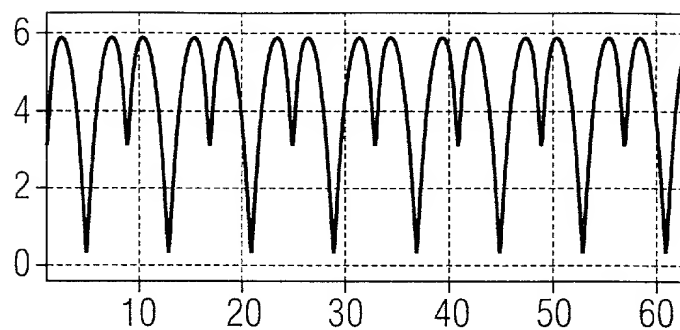


FIG 4b

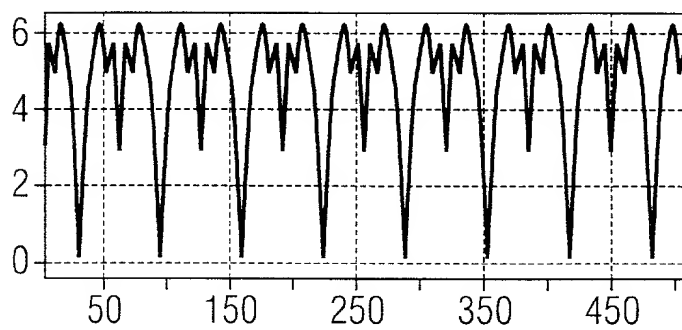


FIG 4c

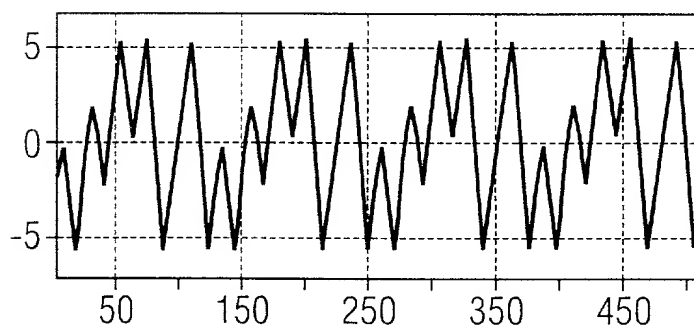
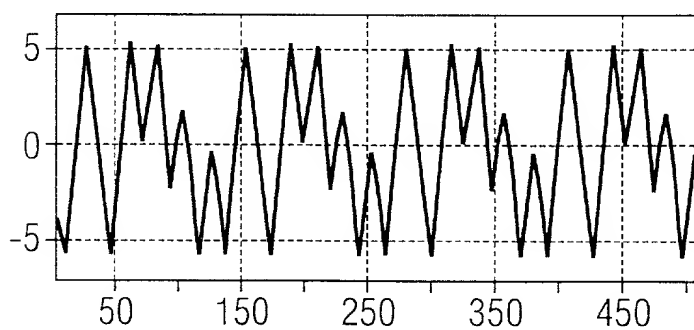
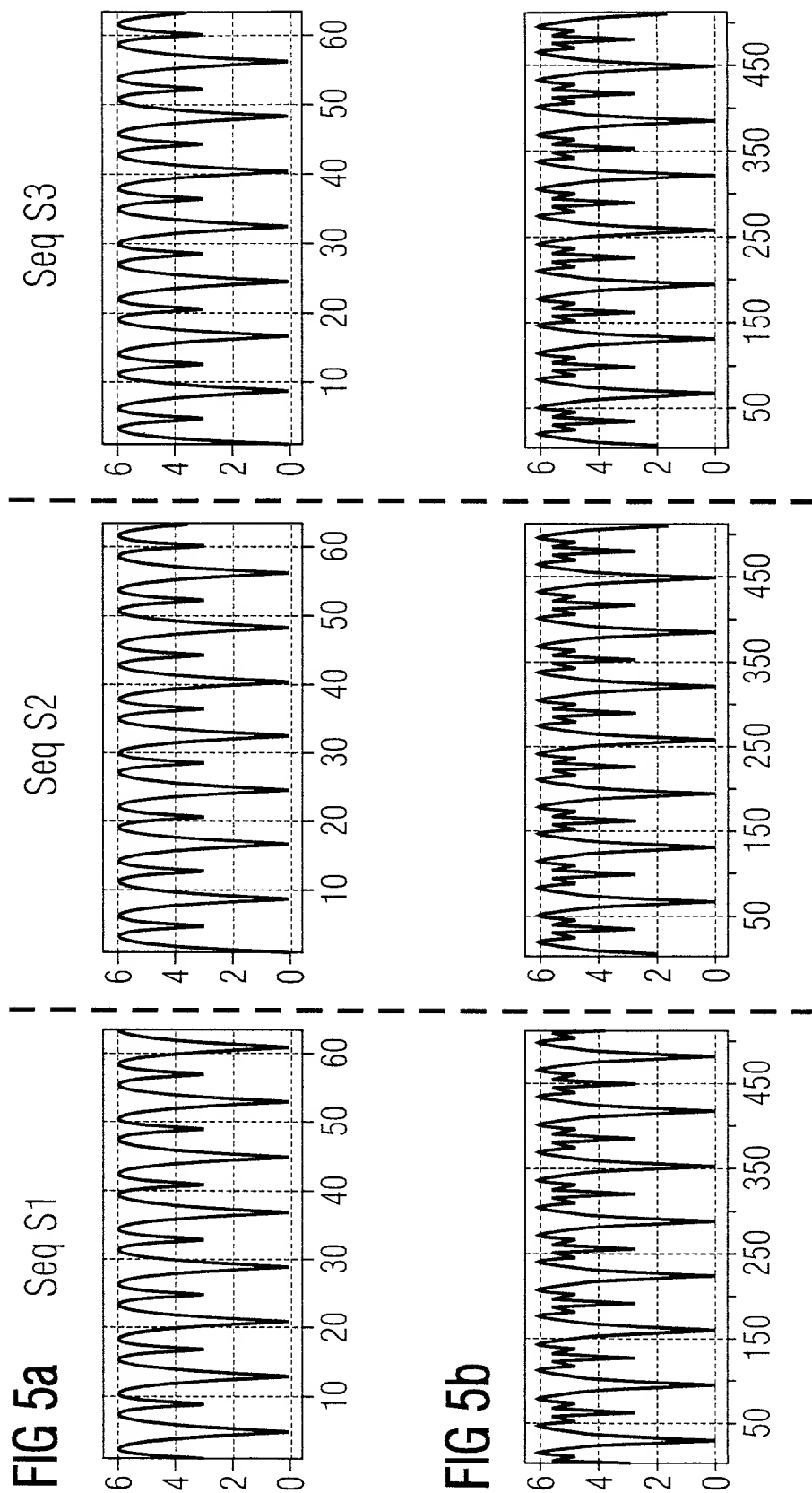


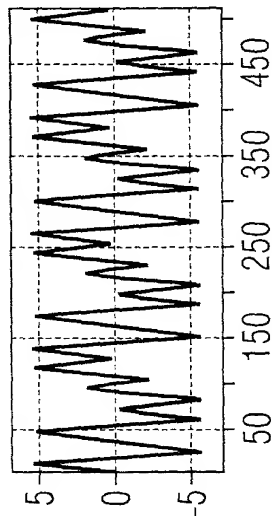
FIG 4d



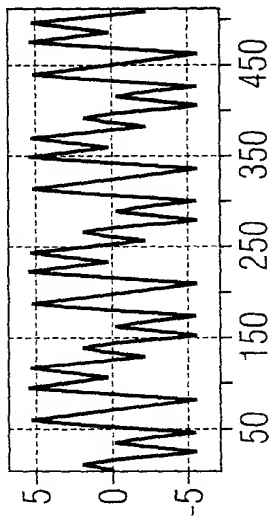


**FIG 5c**

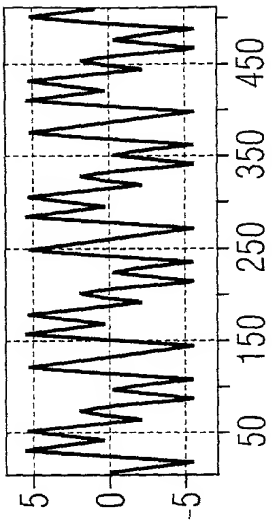
Seq S1



Seq S2



Seq S3



**FIG 5d**

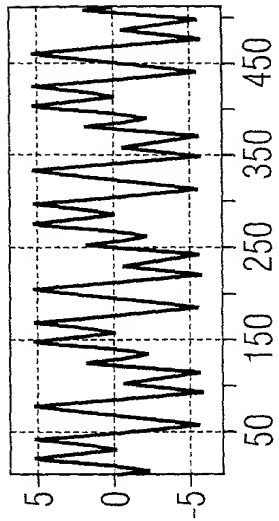
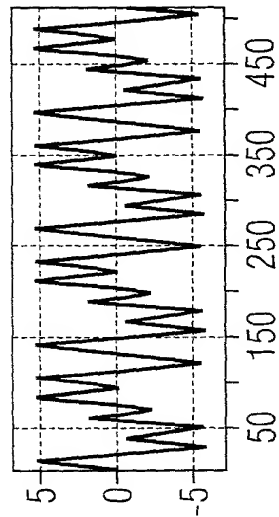
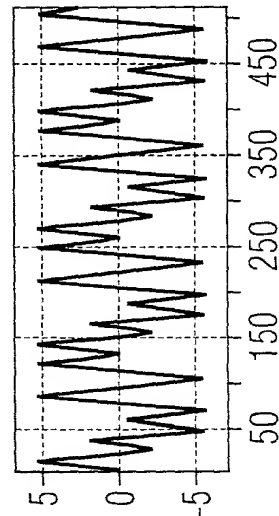


FIG 6

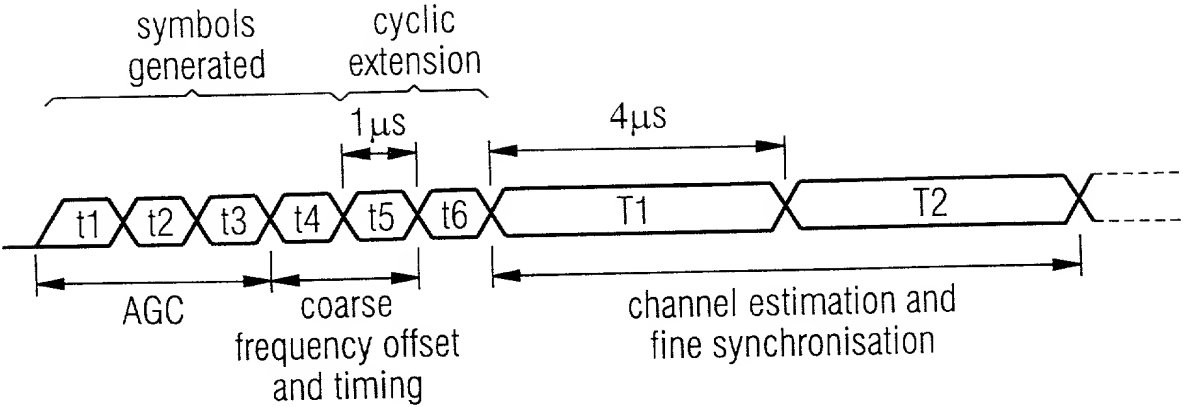


FIG 7

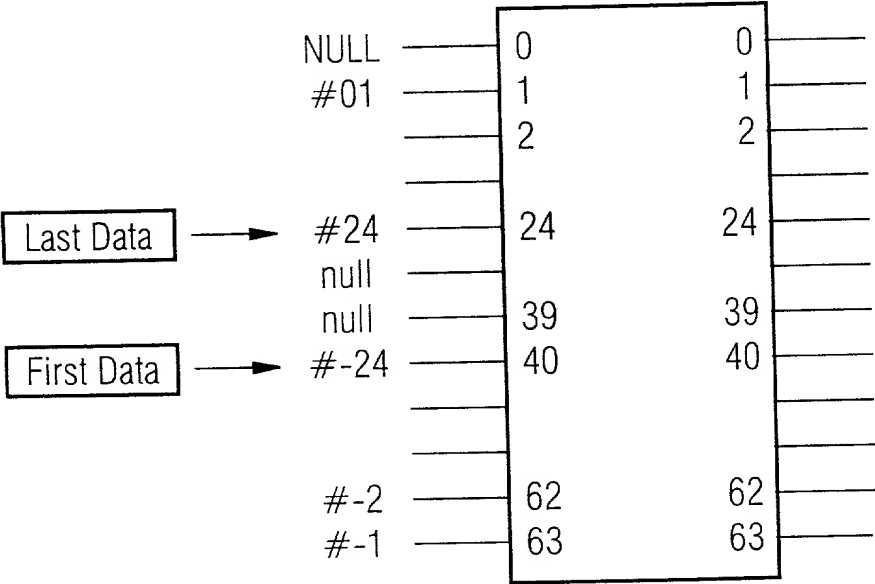


FIG 8a

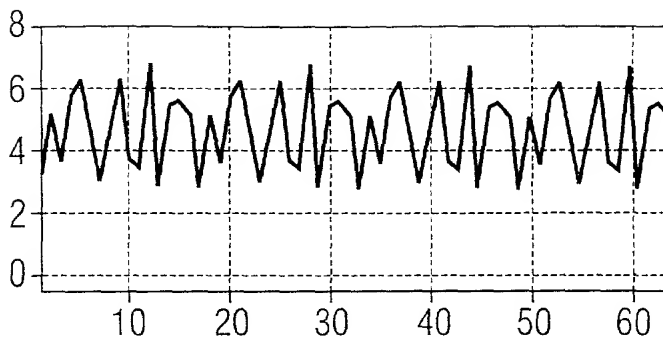


FIG 8b

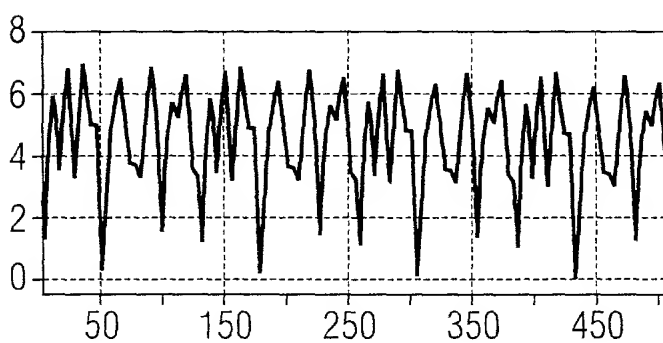


FIG 8c

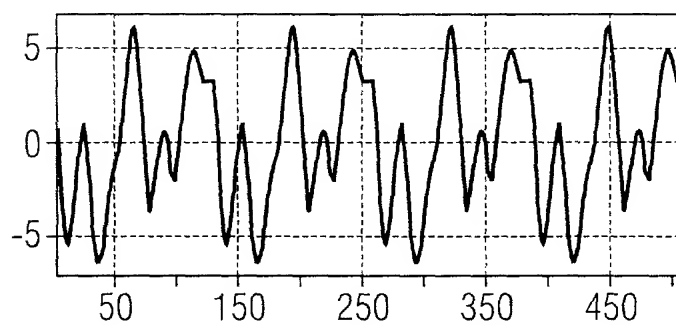
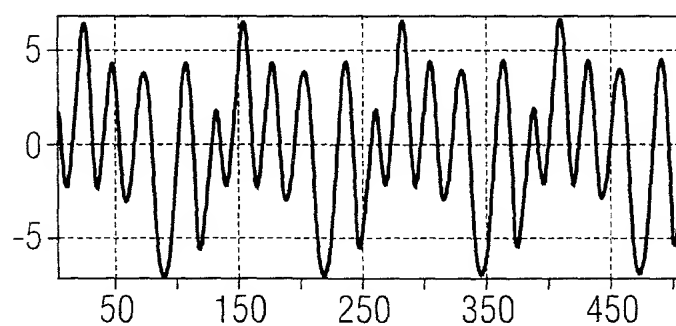
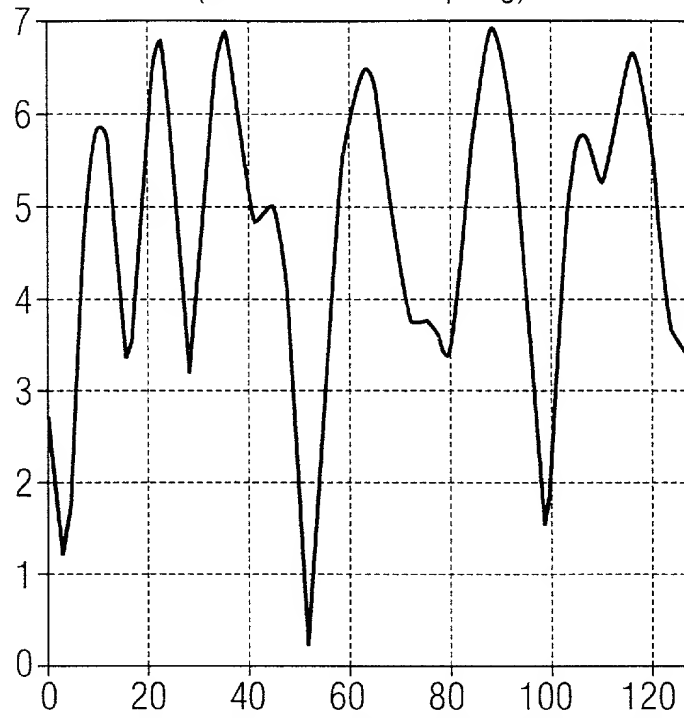


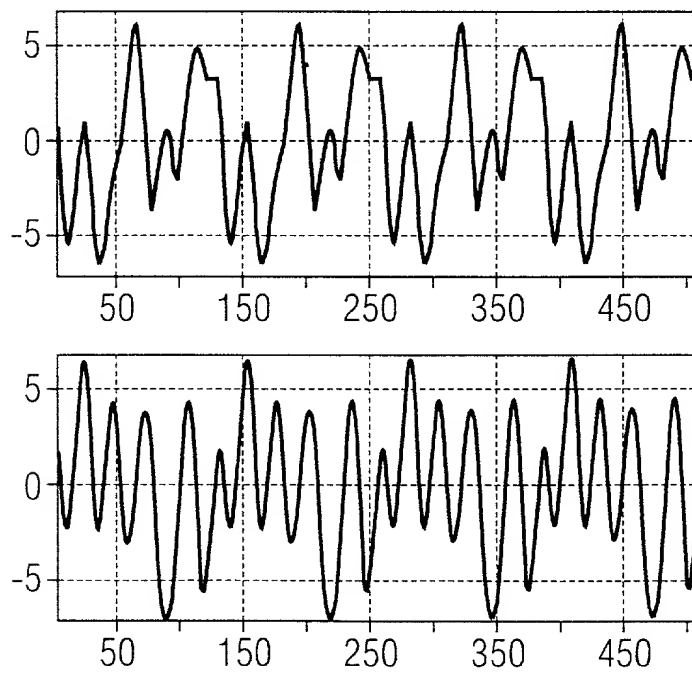
FIG 8d



Time domain signal (magnitude) using the state of the art  
(8-times oversampling)

**FIG 9a**

Signal (In and Quad part) using state of the art sequence  
(8-times oversampling)

**FIG 9b**

PAPR: 3.01 dB  
Dynamic Range: 30.82 dB



Time domain signal (magnitude) using 'Seq-Alt1'  
(8-times oversampling)

FIG 10a

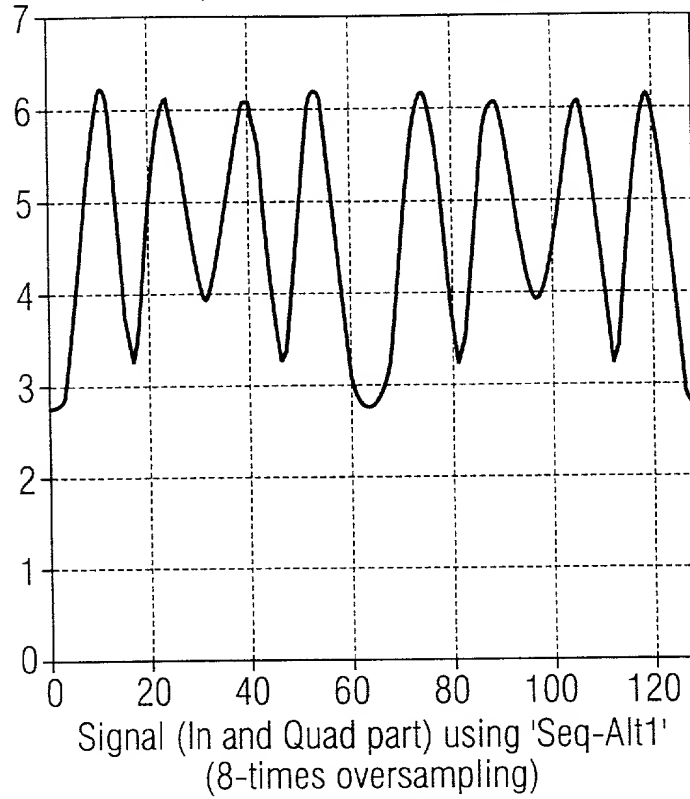
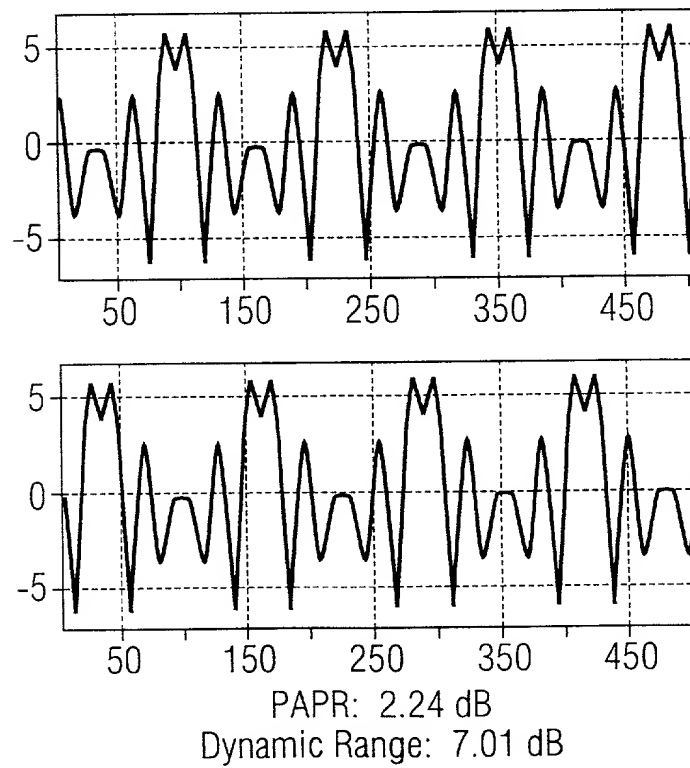


FIG 10b



DECLARATION FOR PATENT APPLICATION (JOINT OR SOLE)

(Under 37 CFR § 1.63; with Power of Attorney)

FROMMER LAWRENCE & HAUG LLP

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention ENTITLED:

Synchronisation symbol structure using OFDM based transmission method

the specification of which

\_\_\_\_\_ is attached hereto.

\_\_\_\_\_ was filed on \_\_\_\_\_ as Application Serial No. \_\_\_\_\_,

with amendment(s) through \_\_\_\_\_ (if applicable, give dates).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Sec. 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)		(List additional applications on separate page):		Priority Claimed:	
Number:	Country:	Filed (Day/Month/Year):	Yes	No	
99 100 263.5	EP	08/01/1999	X		
99 103 379.6	EP	22/02/1999	X		

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code § 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Sec. 1.56, which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Prior U.S. Application(s) (List additional applications on separate page):

Appln. Ser. Number:	Filed (Day/Month/Year):	Status (patented, pending, abandoned):
---------------------	-------------------------	--

I hereby appoint WILLIAM S. FROMMER, Registration No. 25,506, and DENNIS M. SMID, Registration No. 34,930 or their duly appointed associate, my attorneys, with full power of substitution and revocation, to prosecute this application, to make alterations and amendments therein, to file continuation and divisional applications thereof, to receive the Patent, and to transact all business in the Patent and Trademark Office and in the Courts in connection therewith, and specify that all communications about the application are to be directed to the following correspondence address:

WILLIAM S. FROMMER, Esq.  
c/o FROMMER LAWRENCE & HAUG LLP  
745 Fifth Avenue  
New York, New York 10151

Direct all telephone calls to:  
(212) 588-0800  
to the attention of:  
WILLIAM S. FROMMER

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

INVENTOR(S):

Signature: Ralf Böhnke

Date: 8. Sept. 99

Full name of sole or first inventor: Ralf BÖHNKE

Residence:

Citizenship: Esslingen, Germany

German

Signature: Thomas Dölle

Date: 10.09.99

Full name of 2nd joint inventor (if any): Thomas DÖLLE

Residence:

Citizenship: Stuttgart, Germany

German

Signature: Tino Kenschak

Date: 10.09.99

Full name of 3rd joint inventor (if any): Tino KONSCHAK

Residence:

Citizenship: Stuttgart, Germany

German

(Similarly list additional inventors on separate page)

Post Office Address(es) of inventor(s):

(If all inventors have the same post office address)

c/o Sony International (Europe) GmbH  
Stuttgart Technology Center  
Stuttgarter Straße 106  
D-70736 Fellbach, Germany

Note: In order to qualify for reduced fees available to Small Entities, each inventor and any other individual or entity having rights to the invention must also sign an appropriate separate "Verified Statement (Declaration) Claiming (or Supporting a Claim by Another for) Small Entity Status" form (e.g. for Independent Inventor, Small Business Concern, Nonprofit Organization, individual Non-Inventor).

Note: A post office address must be provided for each inventor.